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Srinivasan et al.

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(54) **ACTIVITY MONITORING DEVICE AND METHOD**

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A61B 5/00 (2006.01)
G06F 19/00 (2011.01)

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USPC **600/595**; 600/587

(58) **Field of Classification Search**
USPC 600/587, 595
See application file for complete search history.

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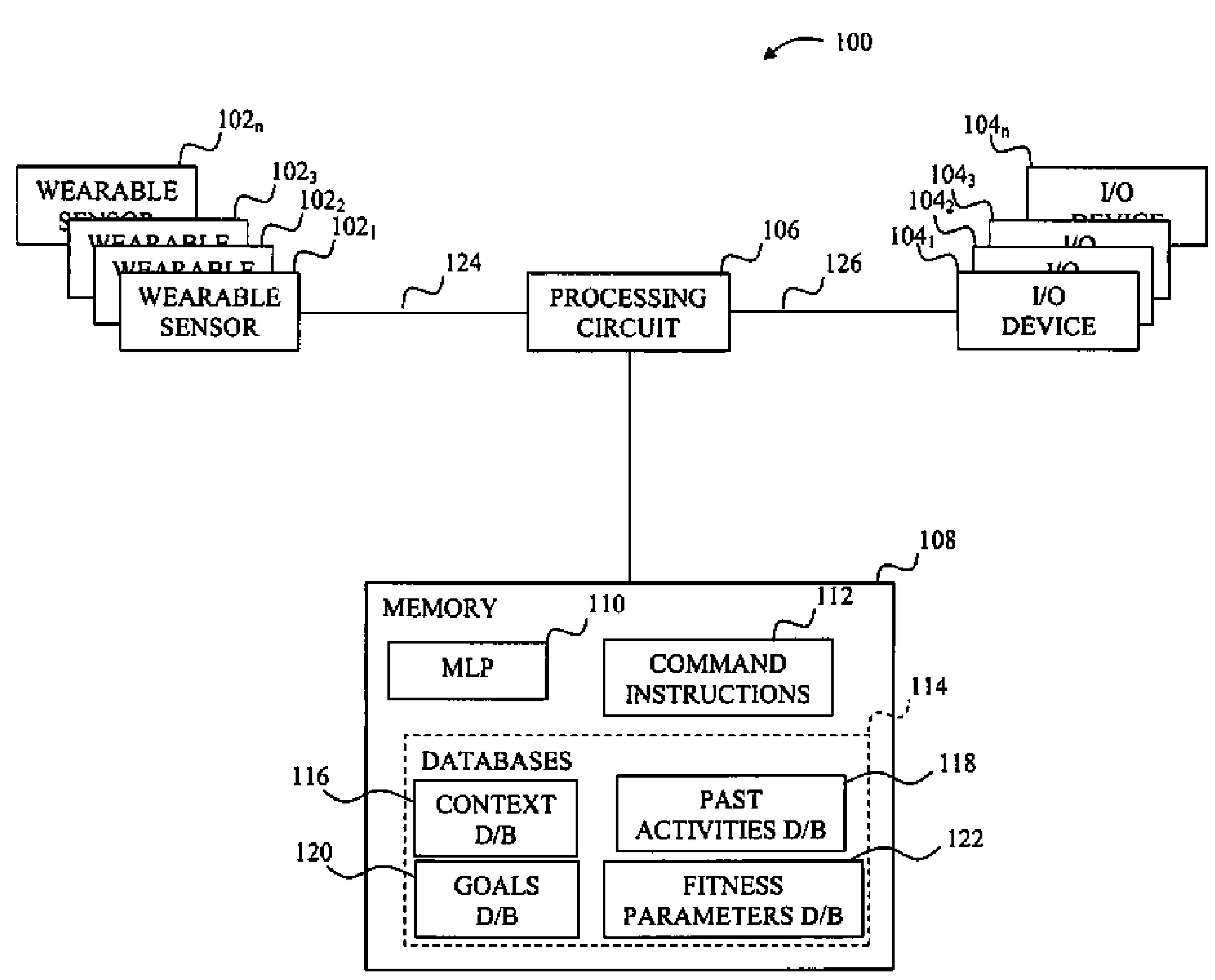
(74) *Attorney, Agent, or Firm* — Maginot Moore & Beck LLP

(57) **ABSTRACT**

A physical activity monitoring method and system in one embodiment includes a communications network, a wearable sensor device configured to generate physiologic data associated with a sensed physiologic condition of a wearer, and to generate context data associated with a sensed context of the wearer, and to transmit the physiologic data and the context data over the communications network, a memory for storing the physiologic data and the context data, a computer and a computer program executed by the computer, wherein the computer program comprises computer instructions for rendering first data associated with the physiologic data and second data associated with the context data, and a user interface operably connected to the computer for rendering the first data and the second data.

11 Claims, 8 Drawing Sheets



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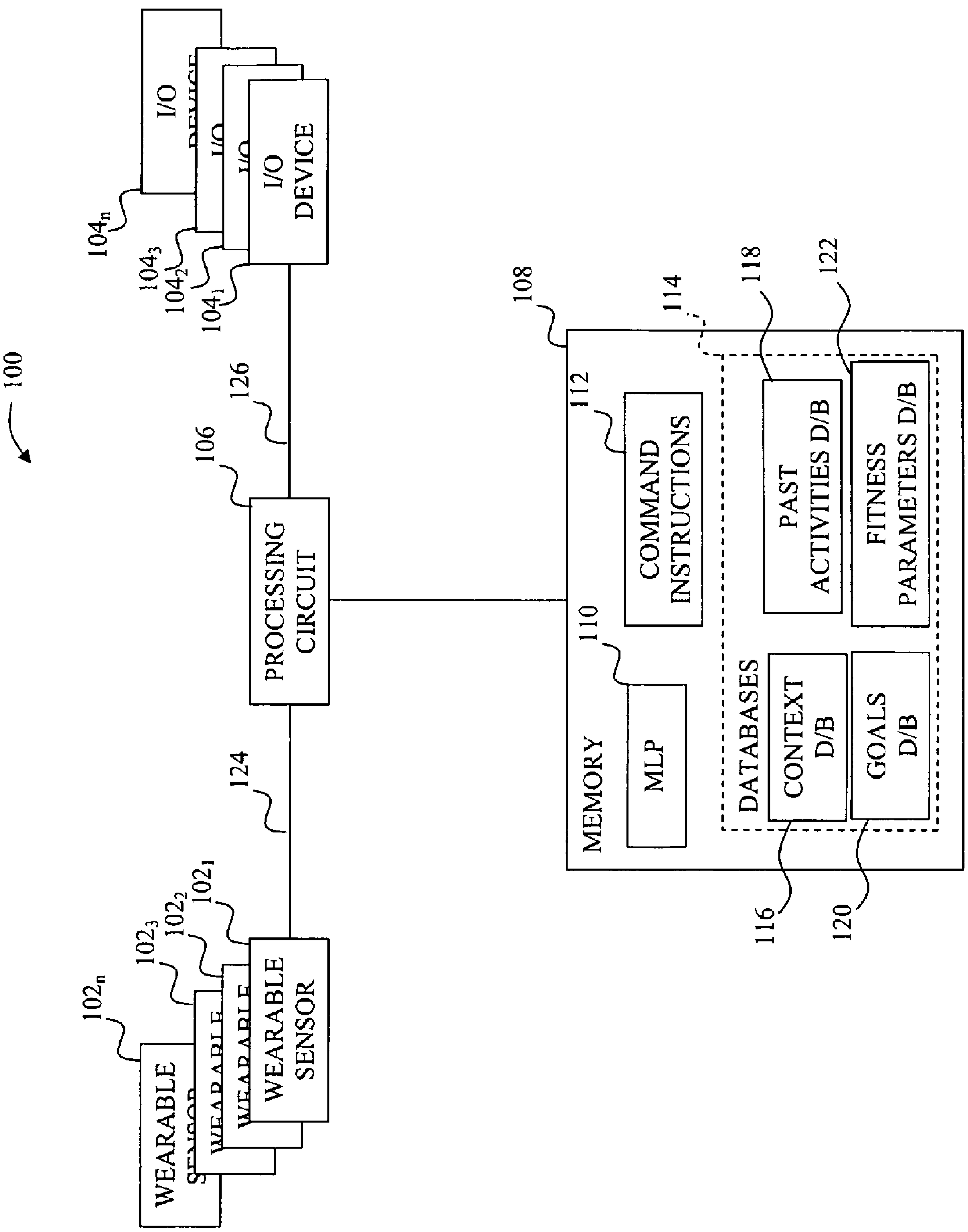

100
WEARABLE SENSOR
102_1
102_2
102_3
102_n
124
PROCESSING CIRCUIT
106
126
I/O DEVICE
104_1
104_2
104_3
104_n
108
MEMORY
MLP
110
COMMAND INSTRUCTIONS
112
DATABASES
114
CONTEXT D/B
116
GOALS D/B
120
PAST ACTIVITIES D/B
118
FITNESS PARAMETERS D/B
122

FIG. 1

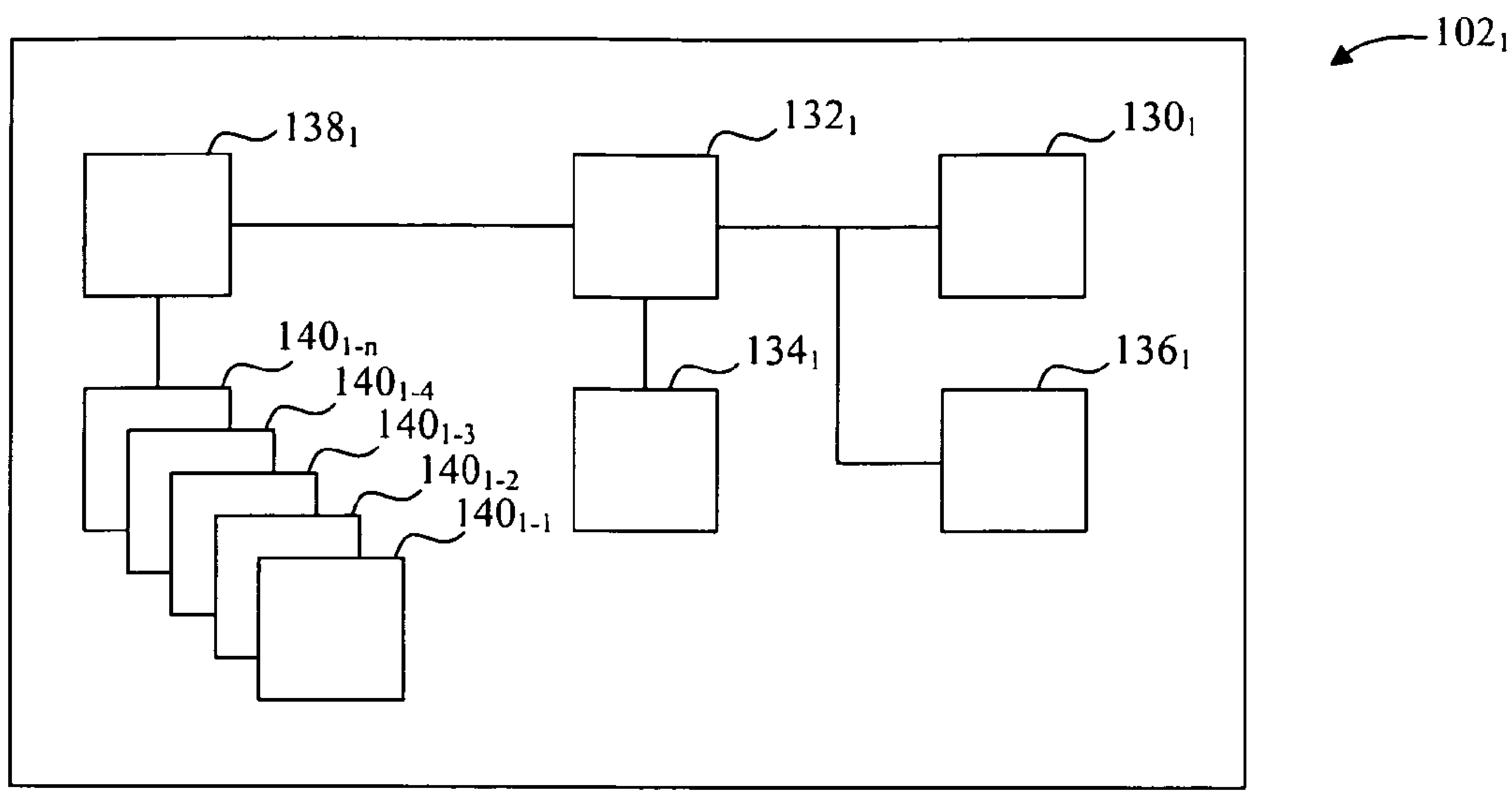

102_1
138_1
132_1
130_1
140_{1-n}
140_{1-4}
140_{1-3}
140_{1-2}
140_{1-1}
134_1
136_1

FIG. 2

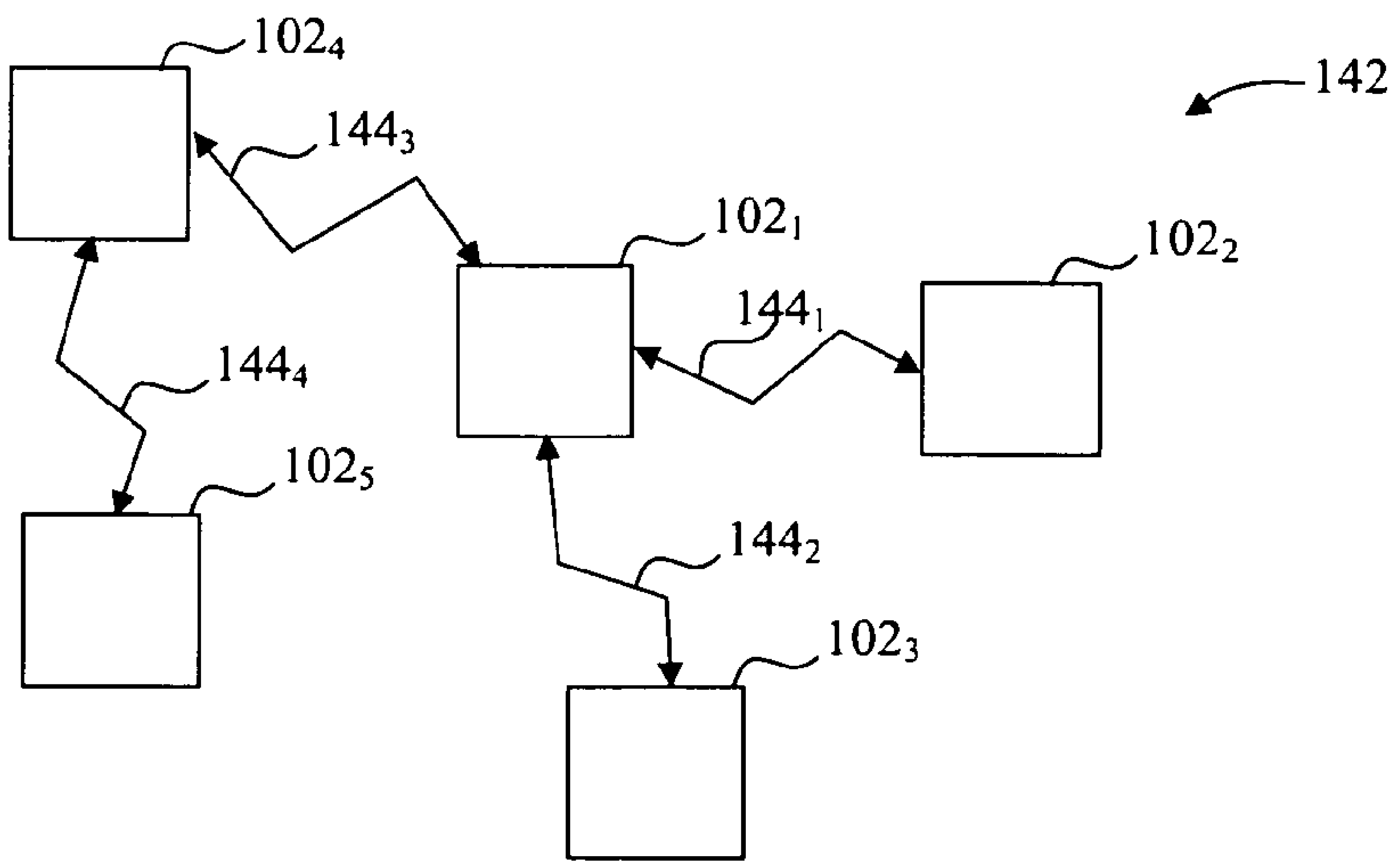

102_4
144_3
142
102_1
102_2
144_1
144_4
102_5
144_2
102_3

FIG. 3

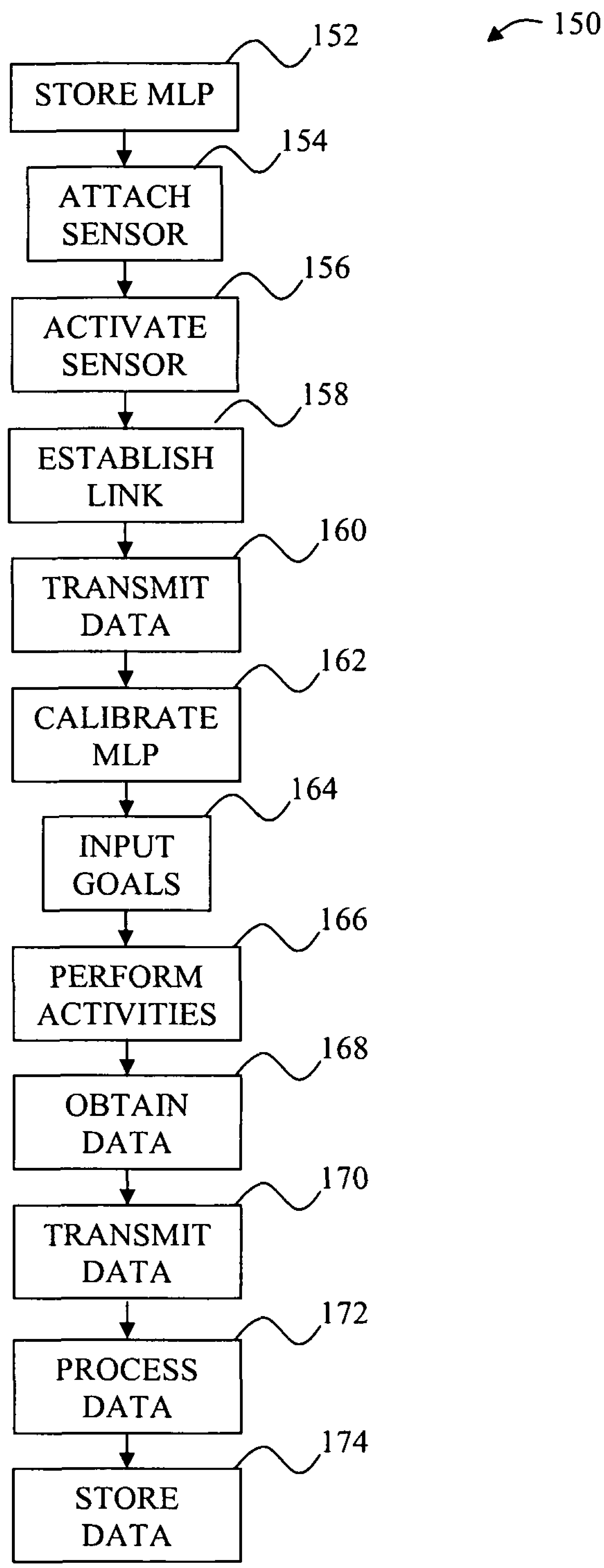

150
152
STORE MLP
154
ATTACH SENSOR
156
ACTIVATE SENSOR
158
ESTABLISH LINK
160
TRANSMIT DATA
162
CALIBRATE MLP
164
INPUT GOALS
166
PERFORM ACTIVITIES
168
OBTAIN DATA
170
TRANSMIT DATA
172
PROCESS DATA
174
STORE DATA

FIG. 4

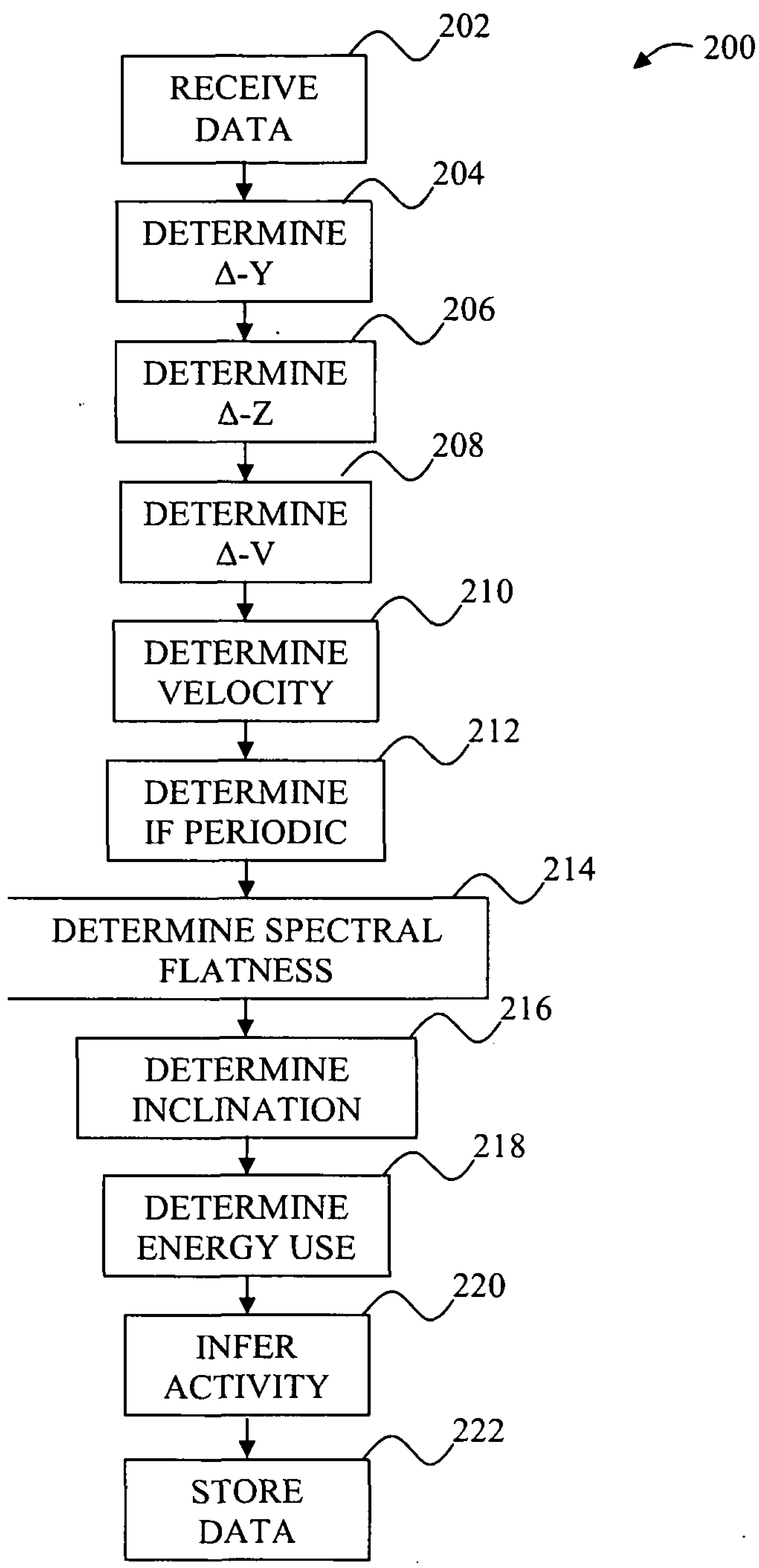

200
202
RECEIVE DATA
204
DETERMINE Δ-Y
206
DETERMINE Δ-Z
208
DETERMINE Δ-V
210
DETERMINE VELOCITY
212
DETERMINE IF PERIODIC
214
DETERMINE SPECTRAL FLATNESS
216
DETERMINE INCLINATION
218
DETERMINE ENERGY USE
220
INFER ACTIVITY
222
STORE DATA

FIG. 5

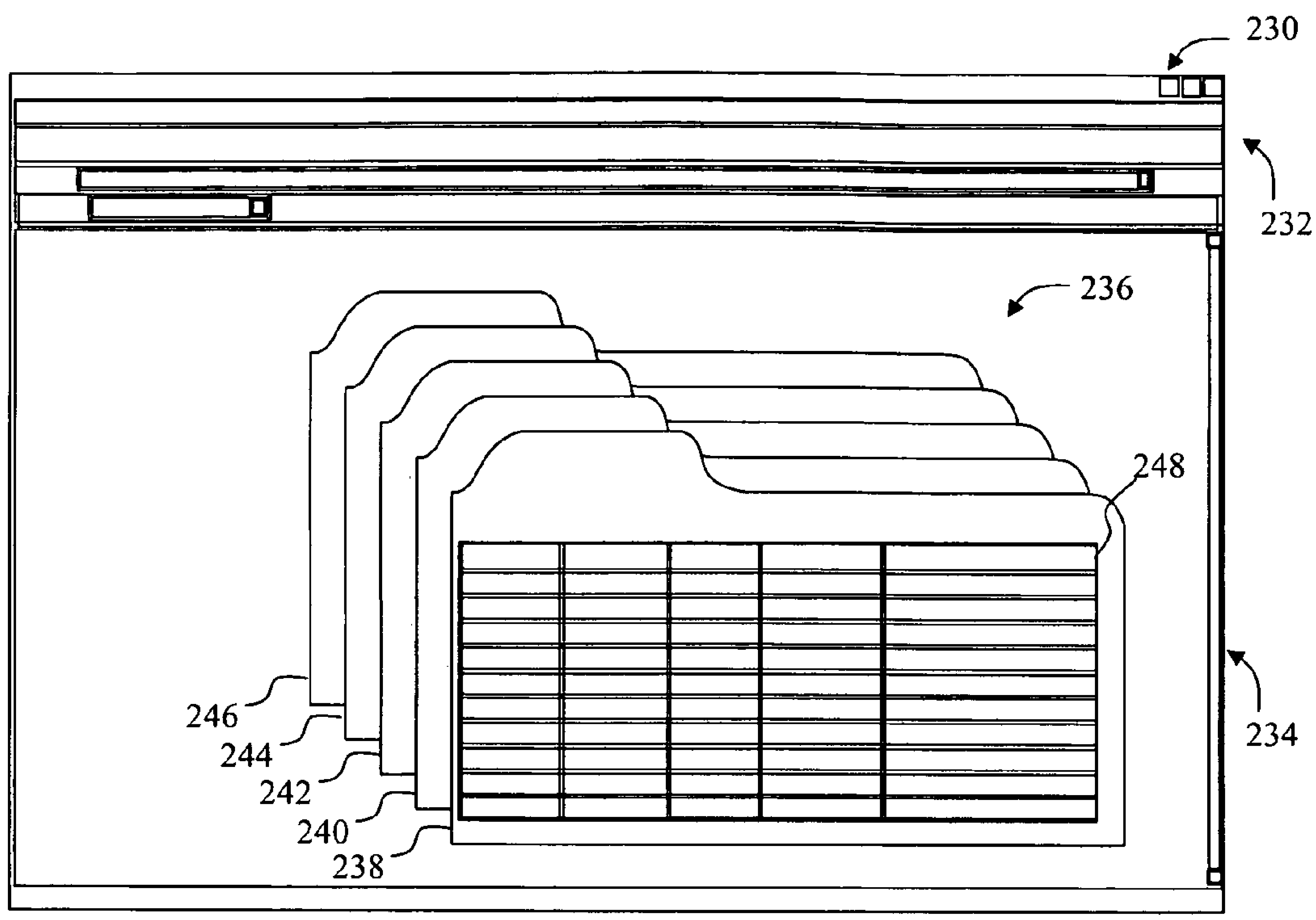

230
232
236
248
234
246
244
242
240
238

FIG. 6

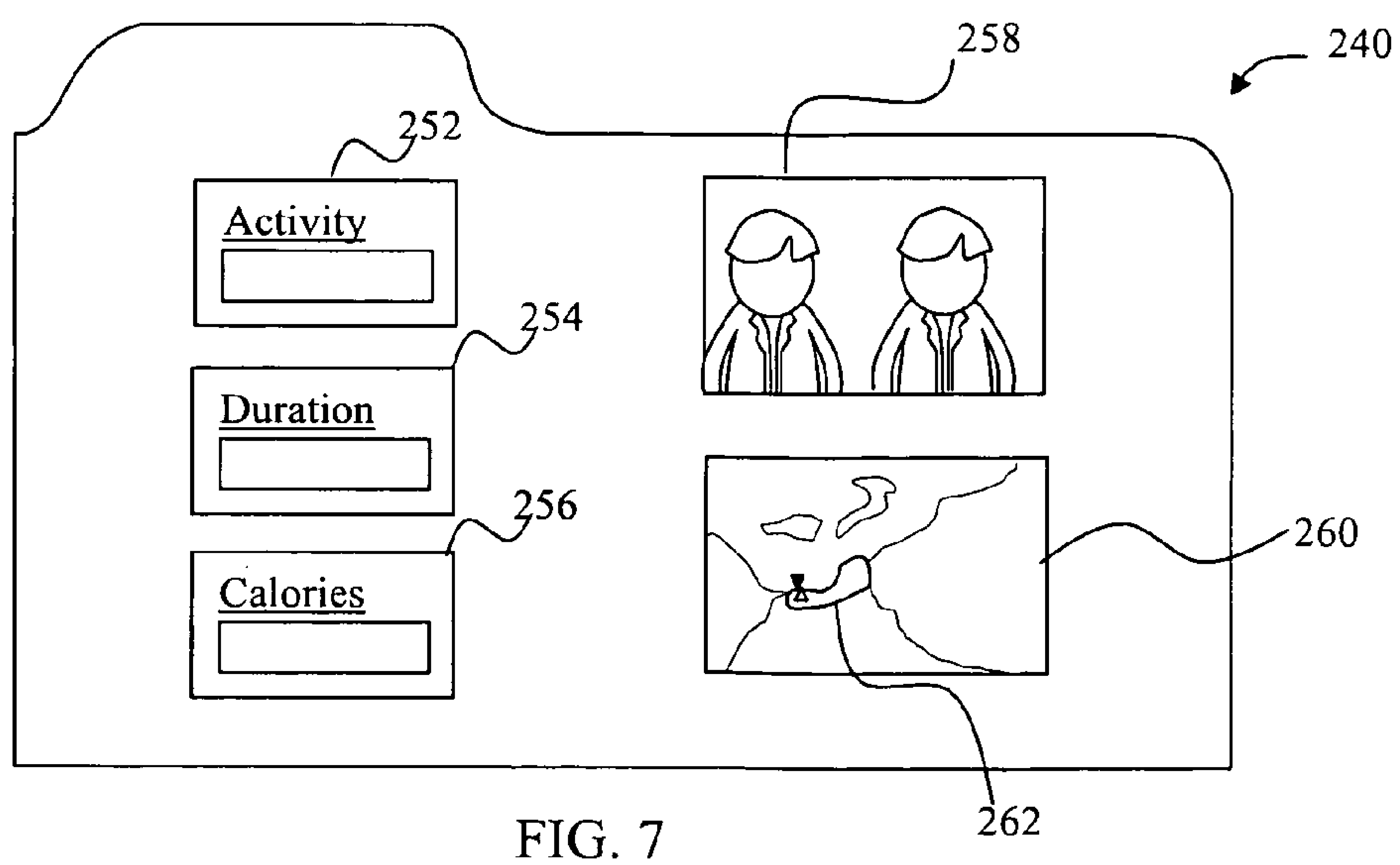

258
240
252
Activity
254
Duration
256
Calories
260
262

FIG. 7

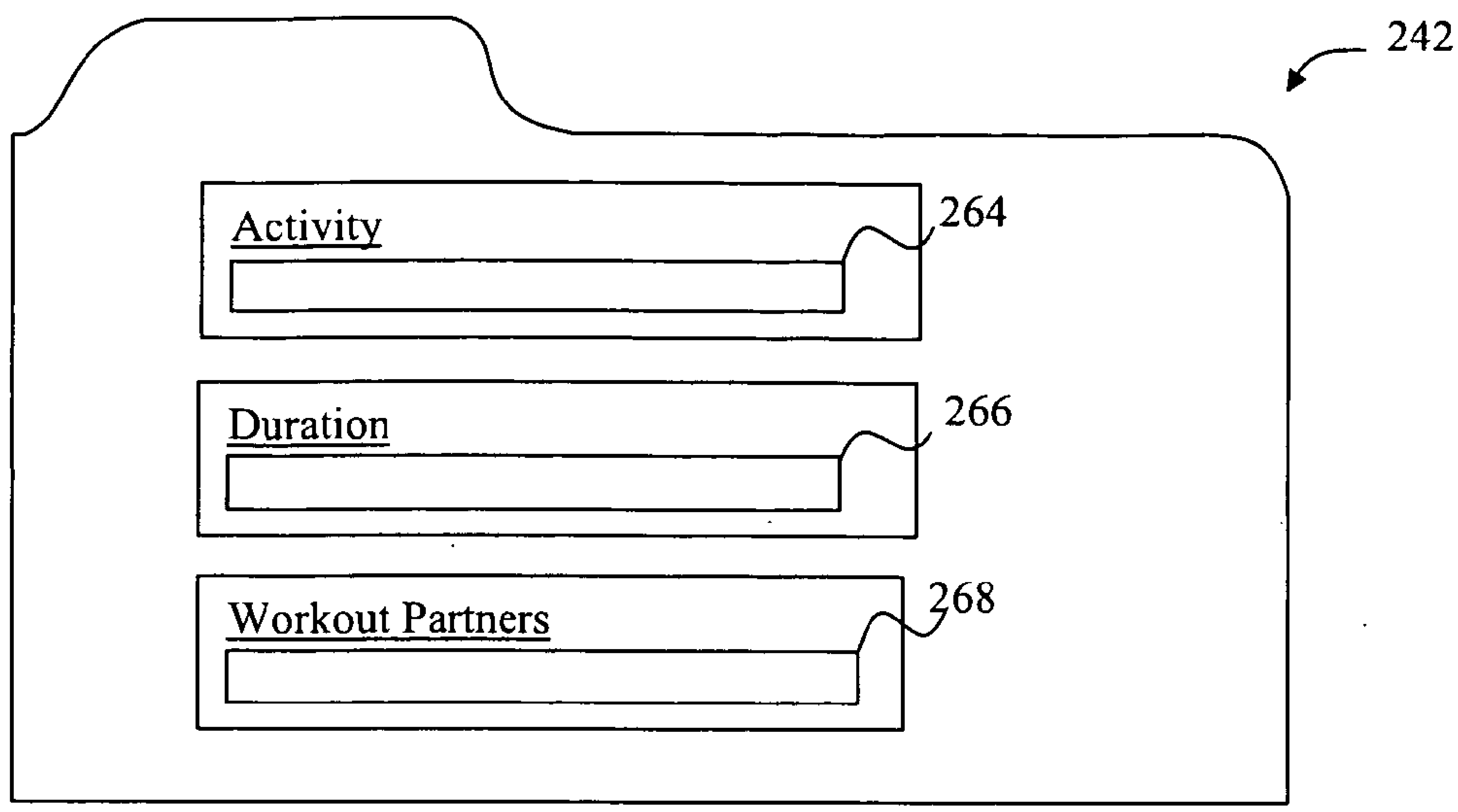

242
Activity
264
Duration
266
Workout Partners
268

FIG. 8

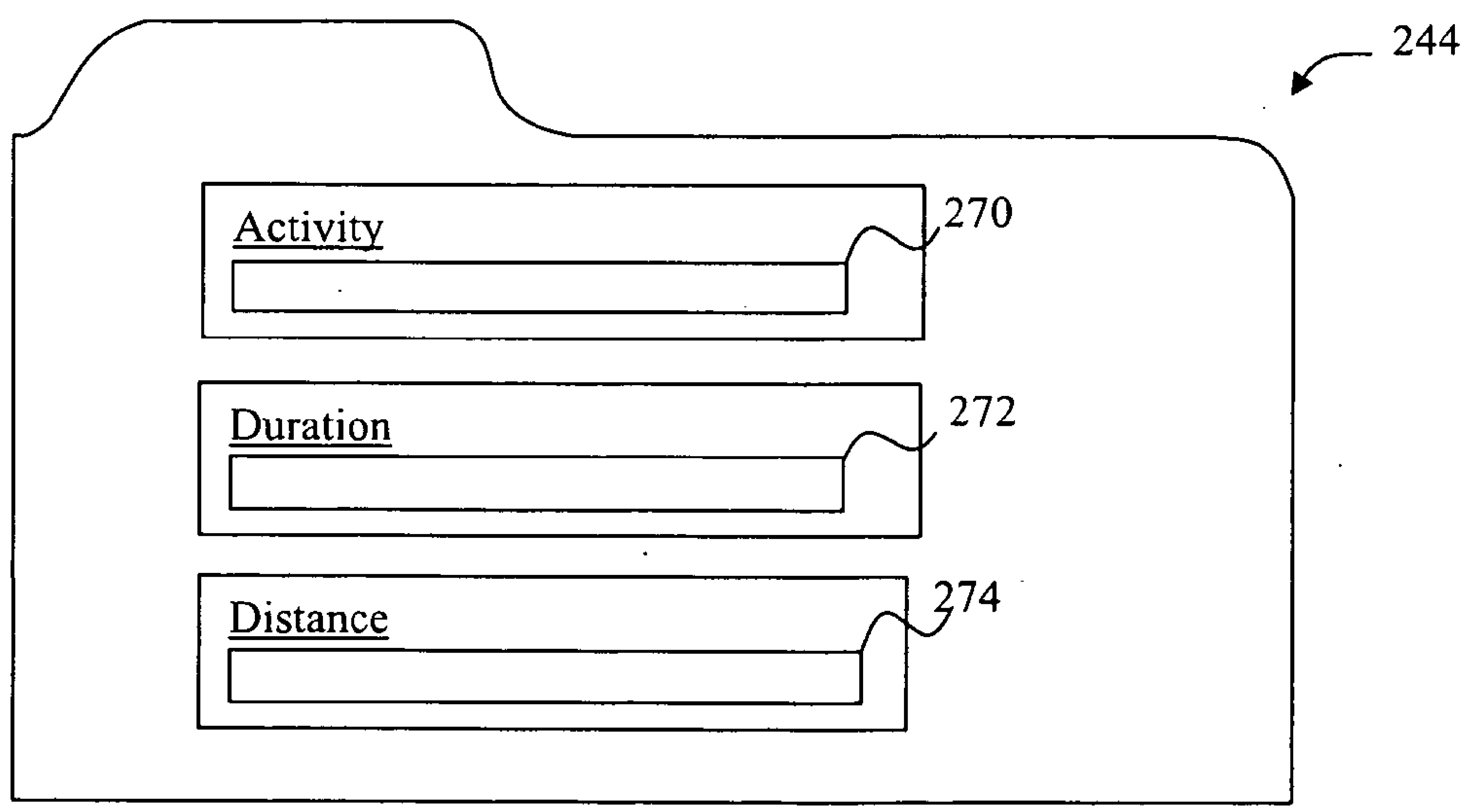
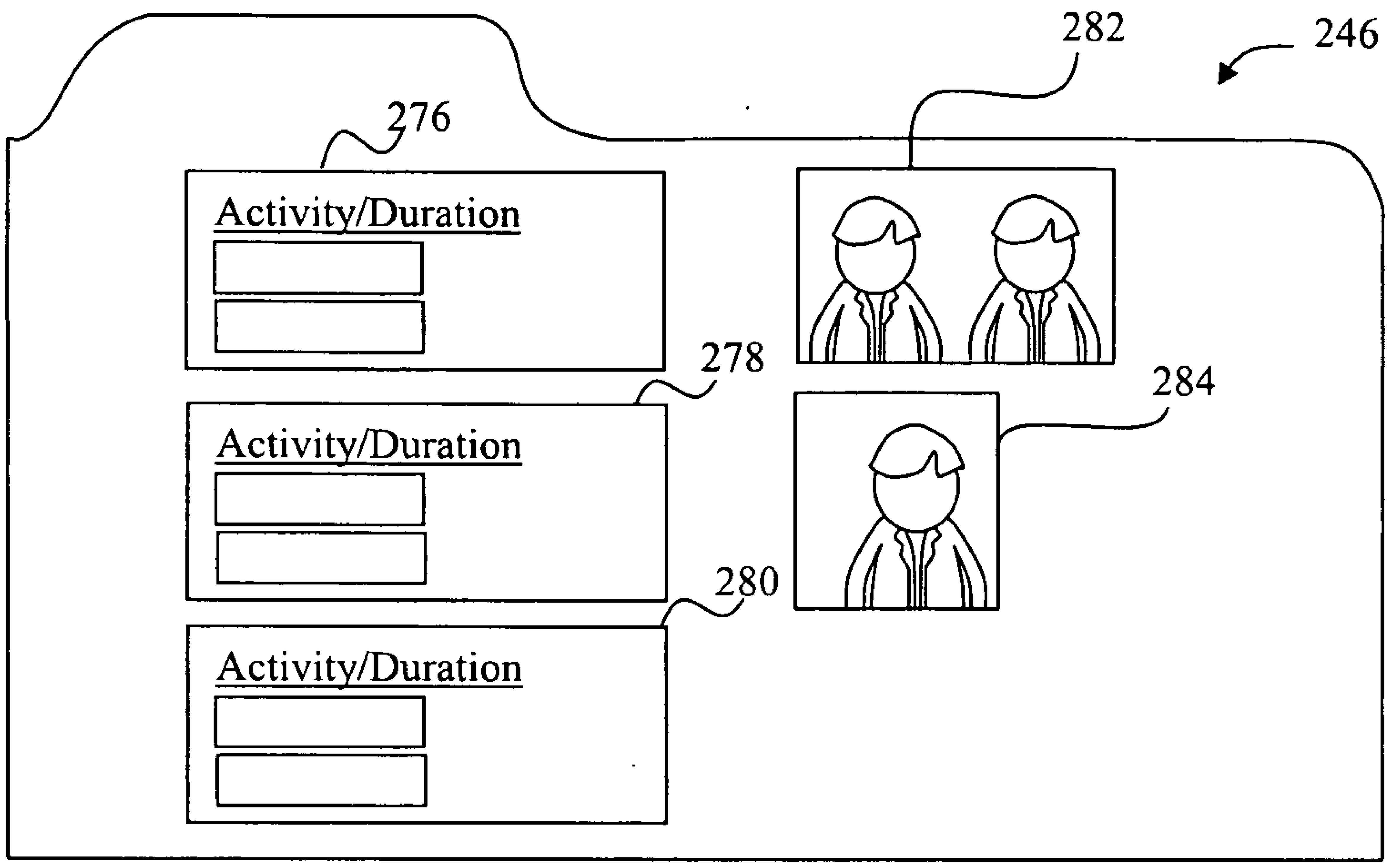

244
Activity
270
Duration
272
Distance
274

FIG. 9



282
246
276
Activity/Duration
278
Activity/Duration
284
280
Activity/Duration

FIG. 10

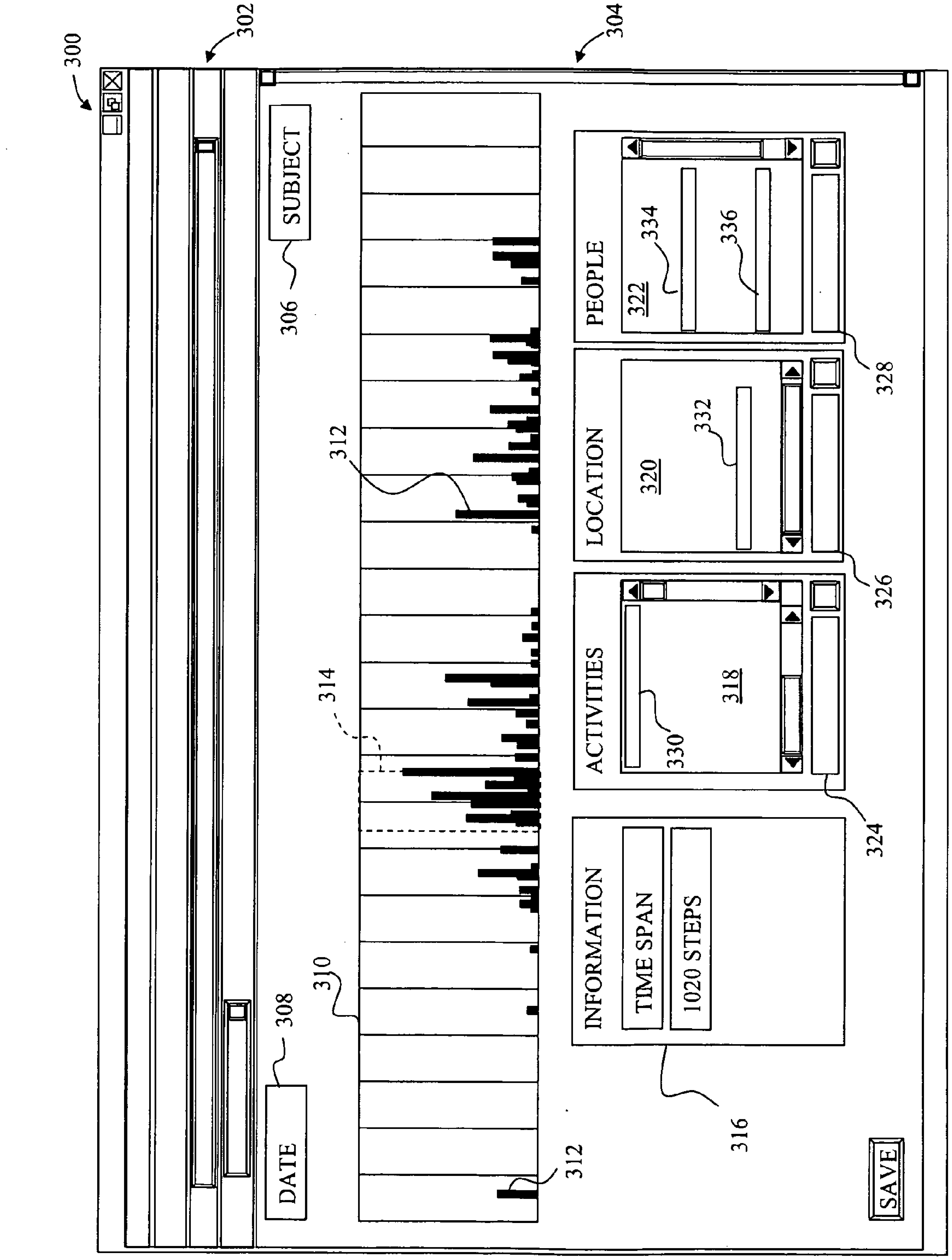

300
302
304
SUBJECT
306
DATE
308
310
312
314
312
INFORMATION
TIME SPAN
1020 STEPS
316
ACTIVITIES
318
330
324
LOCATION
320
332
326
PEOPLE
322
334
336
328
SAVE

FIG. 11

ACTIVITY MONITORING DEVICE AND METHOD

FIELD

This invention relates to wearable monitoring devices.

BACKGROUND

Physical fitness has been a growing concern for both the government as well as the health care industry due to the decline in the time spent on physical activities by both young teens as well as older adults. Self monitoring of individuals has proven to be helpful in increasing awareness of individuals to their activity habits. By way of example, self-monitoring of sugar levels by a diabetic helps the diabetic to modify eating habits leading to a healthier lifestyle.

Self-monitoring and precisely quantizing physical activity has also proven to be important in disease management of patients with chronic diseases, many of which have become highly prevalent in the western world. A plethora of different devices and applications have surfaced to serve the needs of the community ranging from simple pedometers to complex web-based tracking programs.

Wearable devices and sensors have seen a tremendous global growth in a range of applications including monitoring physical activity. Several physical activity monitoring systems incorporate a variety of sensors which store the sensor data on a wearable device and process the data offline in a separate device. Typically, the known systems require proactive or reactive specification of the physical actions performed by the user. Additionally, while known systems are able, to some extent, to ascertain the general nature of activity that an individual is undertaking, the systems are not able to provide detailed information as to the context in which the activity is being undertaken.

Micro-electromechanical system (MEMS) sensors, which have a small form factor and exhibit low power consumption without compromising on performance, have received increased attention for incorporation into wearable sensors. For example, inertial MEMS sensors such as accelerometers can be placed into an easy and light portable device to be worn by users.

Accordingly, there is a need for smarter applications and wearable devices that track, record and report physical activities of the wearer. It would be beneficial if such a device did not require user intervention during the course of the activity. A further need exists for such a system that can deduce the nature of the physical activity. A system which performed physical activity monitoring while providing information regarding the context of the activity would be beneficial.

SUMMARY

A physical activity monitoring method and system in one embodiment includes a communications network, a wearable sensor device configured to generate physiologic data associated with a sensed physiologic condition of a wearer, and to generate context data associated with a sensed context of the wearer, and to transmit the physiologic data and the context data over the communications network, a memory for storing the physiologic data and the context data, a computer and a computer program executed by the computer, wherein the computer program comprises computer instructions for rendering first data associated with the physiologic data and second data associated with the context data, and a user interface operably connected to the computer for rendering the first data and the second data.

In accordance with another embodiment, a method of displaying data associated with physical activities comprising storing a multilayer perceptron model, transmitting first physiologic data associated with a first sensed physiologic condition of a wearer, calibrating the multilayer perceptron model with the first transmitted physiologic data, transmitting second physiologic data associated with a second sensed physiologic condition of the wearer during an activity, using the stored multilayer perceptron model to determine at least one characteristic of the wearer during the activity, determining the nature of the activity based upon the determined at least one characteristic, and displaying first data associated with the second physiologic data and second data associated with the determined nature of the activity.

In yet another embodiment, a method of monitoring physical activity includes attaching a sensor to a wearer, activating the sensor, generating physiologic data associated with a sensed physiologic condition of the wearer during a wearer activity, generating context data associated with a sensed context of the wearer during the wearer activity, analyzing the physiologic data with a multilayer perceptron, identifying the wearer activity based upon the analyses, and displaying the identity of the activity and the context data.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** depicts a block diagram of a physical activity monitoring network including wearable sensor devices in accordance with principles of the present invention;

FIG. **2** depicts a schematic of a wearable sensor of FIG. **1** including at least one communication circuit and at least one sensor suite;

FIG. **3** depicts the wearable sensors of FIG. **1** connected into a piconet;

FIG. **4** depicts a process that may be controlled by the processor of FIG. **1** for obtaining physical activity monitoring data from the wearable sensors of FIG. **1**;

FIG. **5** depicts a process of analyzing data from a wearable sensor of FIG. **1** to generate an inference as to the activity of a subject wearing a wearable sensor using a multilayer perceptron;

FIG. **6** depicts a screen that may be transmitted over a communications link such as the Internet and used to display obtained physical activity monitoring data from the wearable sensors of FIG. **1**;

FIG. **7** depicts the contents of an exemplary activity information folder rendered within the screen of FIG. **6**;

FIG. **8** depicts the contents of an exemplary record activity folder rendered within the screen of FIG. **6**;

FIG. **9** depicts the contents of an exemplary goals folder rendered within the screen of FIG. **6**;

FIG. **10** depicts the contents of an exemplary activity review folder rendered within the screen of FIG. **6**; and

FIG. **11** depicts an alternative screen that may be accessed by a user to review activity of a subject over a twenty-four hour period including a graphic display of energy used, a summary of activity within a focus window, identification of activities within the focus window, the location at which the activities in the focus window were performed, and others accompanying the subject during performance of the activity.

DESCRIPTION

For the purposes of promoting an understanding of the principles of the invention, reference will now be made to the embodiments illustrated in the drawings and described in the following written specification. It is understood that no limitation to the scope of the invention is thereby intended. It is further understood that the present invention includes any alterations and modifications to the illustrated embodiments and includes further applications of the principles of the invention as would normally occur to one skilled in the art to which this invention pertains.

Referring to FIG. **1**, there is depicted a representation of a physical activity monitoring network generally designated **100**. The network **100** includes a plurality of wearable sensors $\mathbf{102}_x$, input/output (I/O) devices $\mathbf{104}_x$, a processing circuit **106** and a memory **108**. The I/O devices $\mathbf{104}_x$ may include a user interface, graphical user interface, keyboards, pointing devices, remote and/or local communication links, displays, and other devices that allow externally generated information to be provided to the processing circuit **106**, and that allow internal information of the processing circuit **106** to be communicated externally.

The processing circuit **106** may suitably be a general purpose computer processing circuit such as a microprocessor and its associated circuitry. The processing circuit **106** is operable to carry out the operations attributed to it herein.

Within the memory **108** is a multilayer perceptron (MLP) **110** and program instructions **112**. The program instructions **112**, which are described more fully below, are executable by the processing circuit **106** and/or any other components as appropriate.

The memory **108** also includes databases **114**. The databases **114** include a context database **116**, a past activities database **118**, a goals database **120**, and a fitness parameters database **122**. In one embodiment, the databases are populated using object oriented modeling. The use of object oriented modeling allows for a rich description of the relationship between various objects.

A communications network **124** provides communications between the processing circuit **106** and the wearable sensors $\mathbf{102}_x$ while a communications network **126** provides communications between the processing circuit **106** and the I/O devices $\mathbf{104}_x$. In alternative embodiments, some or all of the communications network **124** and the communications network **126** may include shared components.

In the embodiment described herein, the communications network **124** is a wireless communication scheme implemented as a wireless area network. A wireless communication scheme identifies the specific protocols and RF frequency plan employed in wireless communications between sets of wireless devices. To this end, the processing circuit **106** employs a packet-hopping wireless protocol to effect communication by and among the processing circuit **106** and the wearable sensors $\mathbf{102}_x$.

Each of the wearable sensors $\mathbf{102}_x$ in this embodiment are identical and are described in more detail with reference to the wearable sensor $\mathbf{102}_1$ shown in FIG. **2**. The sensor $\mathbf{102}_1$ includes a network interface $\mathbf{130}_1$, a processor $\mathbf{132}_1$, a non-volatile memory $\mathbf{134}_1$, a micro-electrical mechanical system (MEMS) local RF communication interface $\mathbf{136}_1$, a signal processing circuit $\mathbf{138}_1$, and sensor suites $\mathbf{140}_{1-x}$.

The network interface $\mathbf{130}_1$ is a communication circuit that effectuates communication with one or more components of the communications network **124**. To allow for wireless communication with the other components of the communications network **124**, the network interface $\mathbf{130}_1$ is preferably a radio frequency (RF) modem configured to communicate using a wireless area network communication scheme such as Bluetooth RF modem, or some other type of short range (about 30-100 feet) RF communication modem. Thus, each of the sensors $\mathbf{102}_x$ may communicate with components such as other communication subsystems and the processing circuit **106**.

The network interface $\mathbf{130}_1$ is further operable to, either alone or in conjunction with the processor $\mathbf{132}_1$, interpret messages in wireless communications received from external devices and determine whether the messages should be retransmitted to another external device as discussed below, or processed by the processor $\mathbf{132}_1$. Preferably, the network interface $\mathbf{130}_1$ employs a packet-hopping protocol to reduce the overall transmission power required. In packet-hopping, each message may be transmitted through multiple intermediate communication subsystem interfaces before it reaches its destination as is known in the relevant art.

The processor $\mathbf{132}_1$ is a processing circuit operable to control the general operation of the sensor $\mathbf{102}_1$. In addition, the processor $\mathbf{132}_1$ may implement control functions and information gathering functions used to maintain the databases **114**.

The programmable non-volatile memory $\mathbf{134}_1$, which may be embodied as a flash programmable EEPROM, stores configuration information for the sensor suites $\mathbf{140}_{1-x}$. The programmable non-volatile memory $\mathbf{134}_1$ includes an "address" or "ID" of the wearable sensor $\mathbf{102}_1$ that is appended to any communications generated by the wearable sensor $\mathbf{102}_1$. The memory $\mathbf{134}_1$ further includes set-up configuration information related to the system communication parameters employed by the processor $\mathbf{132}_1$ to transmit information to other devices.

The MEMS local RF communication circuit $\mathbf{136}_1$ may suitably include a Bluetooth RF modem, or some other type of short range (about 30-100 feet) RF communication modem. The use of a MEMS-based RF communication circuit allows for reduced power consumption, thereby enabling the wearable sensor $\mathbf{102}_1$ to be battery operated, if desired. The life of the wearable sensor $\mathbf{102}_1$ may be extended using power management approaches. Additionally, the battery may be augmented or even replaced by incorporating structure within the MEMS module to use or convert energy in the form of vibrations or ambient light. In some embodiments, a single circuit functions as both a network interface and a local RF communication circuit.

The local RF communication circuit $\mathbf{136}_1$ may be self-configuring and self-commissioning. Accordingly, when the wearable sensors $\mathbf{102}_x$ are placed within communication range of each other, they will form a piconet as is known in the relevant art. In the case that a wearable sensor $\mathbf{102}_x$ is placed within range of an existent piconet, the wearable sensor $\mathbf{102}_x$ will join the existent piconet.

Accordingly, the wearable sensors $\mathbf{102}_x$ are formed into one or more communication subsystems **142** as shown in FIG. **3**. The wearable sensors $\mathbf{102}_x$ within the communication subsystem **142** include a hub wearable sensor $\mathbf{102}_1$, and slave wearable sensor $\mathbf{102}_2$, $\mathbf{102}_3$, and $\mathbf{102}_4$. Additionally, a slave transmitter $\mathbf{102}_5$ is within the communication subsystem **142** as a slave to the slave transmitter $\mathbf{102}_4$. The hub sensor $\mathbf{102}_1$ establishes a direct connection with the processing circuit **106** over the network **124**. The slave wearable sensor $\mathbf{102}_2$, $\mathbf{102}_3$, $\mathbf{102}_4$, and $\mathbf{102}_5$ communicate with the processing circuit **106** through the hub sensor $\mathbf{102}_1$. It will be appreciated that a particular communication subsystem **142** may contain more or fewer wearable sensors $\mathbf{102}_x$ than the wearable sensors $\mathbf{102}_x$ shown in FIG. **3**.

Thus, each of the communication circuits $\mathbf{136}_x$ in the wearable sensors $\mathbf{102}_1$, $\mathbf{102}_2$, $\mathbf{102}_3$, and $\mathbf{102}_4$ is used to link with the communication circuits $\mathbf{136}_x$ in the other wearable sensors $\mathbf{102}_x$ to establish piconet links $\mathbf{144}_{1-3}$ (see FIG. **3**). The communication circuits 136_x of the slave wearable sensors 102_4 and 102_5 also establish a piconet link 144_4.

Returning to FIG. **2**, the signal processing circuit 138_1 includes circuitry that interfaces with the sensor suites 140_{1-x}, converts analog sensor signals to digital signals, and provides the digital signals to the processor 132_1. In general, the processor 132_1 receives digital sensor information from the signal processing circuit 138_1, and from other sensors 102_x, and provides the information to the communication circuit **124**.

The sensor suites 140_{1-x} include a sensor suite 140_{1-1} which in this embodiment is a 3-axis gyroscope sensor suite which provides information as to the orientation of the wearable sensor 102_1. Other sensors which may be incorporated into the sensor suites 140_{1-x} include a calorimeter, a pulse sensor, a blood oxygen content sensor, a GPS sensor, and a temperature sensor. One or more of the sensor suites 140_{1-x} may include MEMS technology.

Referring to FIG. **4**, there is depicted a flowchart, generally designated **150**, setting forth an exemplary manner of operation of the network **100**. Initially, the MLP **110** may be stored within the memory **108** (block **152**). The MLP **110** in one embodiment includes 30 hidden layer neurons and 1 output neuron. The activation function for the hidden layer and output layer neurons are hyperbolic tangent sigmoid and log sigmoid, respectively. Next, a wearable sensor 102_x is placed on a subject such as an individual (block **154**). The wearable sensor 102_x is then activated (block **156**). Upon activation of the sensor 102_x, the processor **132** initiates' data capture subroutines. Additionally, the wearable sensor 102_x establishes the communications link **124** with the processing circuit **106** (block **158**). Alternatively, the wearable sensor 102_x may join a piconet or other communication system in communication with the processing circuit **106**.

Initial output from the sensor suites 140_x is passed through the signal processing circuit 138_x to the processor 132_x. The initial sensor data is then transmitted to the processing circuit **106** over the link **124** (block **160**). The initial sensor data is used by the processing circuit **106** to calibrate the MLP **110** (block **162**). Calibration of the MLP **110** provides the MLP **110** with an initial state for the subject wearing the sensor 102_x. For example, the output of the sensor suite 140_{1-1} is used to establish y-axis and z-axis values for the wearer of the sensor 102_x, in a known position such as standing or prostate.

The goals database **120** (block **164**) is then populated. The data used to populate the goals database **120** may be input from one or more of the I/O devices 104_x. Alternatively, the sensor 102_x may be configured with a user interface, allowing the wearer of the sensor 102_x to input goals data.

The wearer then proceeds to perform various physical activities (block **166**). As the activities are performed, data is obtained from the sensor suites 140_x (block **168**). The sensor data is passed through the signal processing circuit 138_x to the processor 132_x. The sensor data is then transmitted to the processing circuit **106** over the link **124** (block **170**). The sensor data is processed by the processing circuit **106** (block **172**) and stored in the databases **114** (block **174**). By way of example, heart rate, respiration rate, temperature, blood oxygen content, and other physical parameters may be stored in the fitness parameters database **122**.

The foregoing actions may be performed in different orders. By way of example, goals may be stored prior to attaching a sensor 102_x to a subject. Additionally, the various actions may be performed by different components of the network **100**. By way of example, in one embodiment, all or portions of the memory **108** may be provided in the sensor 102_x. In such an embodiment, the output of the MLP **110** may be transmitted to a remote location such as a server remote from the sensor for storage.

The MLP **110** in one embodiment is configured to identify the activity in which the wearer of the sensor 102_x is engaged. Accordingly, the MLP **110** is configured to perform the procedure **200** of FIG. **5**. The processing circuit **106** receives a frame of data from the sensor suite 140_{1-1} (block **202**). One frame of data in one embodiment is based upon a ten second sample. Based upon the initial calibration data (block **162** of FIG. **4**) and the most recently received frame data, the change in the orientation of the wearer in the y-axis is determined (block **204**). Similarly, based upon the initial calibration data (block **162** of FIG. **4**) and the most recently received frame data, the change in the orientation of the wearer in the z-axis is determined (block **206**).

The frame data from the sensor suite 140_{1-1} is also used to obtain a three dimensional vector indicative of the acceleration of the wearer (block **208**) and to determine the three dimensional velocity of the wearer (block **210**). Once the acceleration in the z-axis is obtained, the MLP **110** determines whether or not the acceleration in the z-axis is periodic (block **212**). Periodicity is determined by analyzing several frames of frame data using an autocorrelation sequence formed from the z-axis acceleration.

The spectral flatness measure of the acceleration in all three axes is then determined (block **214**). The spectral flatness measure is defined as the ratio of geometric mean to arithmetic mean of the power spectral density coefficients.

The data from the sensor suite 140_{1-1} is further used to determine the relative inclination of the wearer (block **216**) and data indicative of the energy use of the wearer is also obtained from the frame data and the energy expenditure is determined (block **218**). Energy usage may be determined, for example, from data obtained by a sensor suite 140_{1-x} configured as a thermometer or calorimeter.

Thus, the MLP **110** is configured to receive eight static features from a current input frame and eight delta features that capture the difference between the features in the current frame and those in a previous frame. Based upon the foregoing determinations, the MLP **110** infers an activity of the wearer for the time frame associated with the frame data. By way of example, relative inclination, periodicity and spectral flatness help distinguish between sitting, standing and lying-down. Additionally, energy expenditure, velocity, spectral flatness, and periodicity help distinguish between dynamic activities (e.g., walking) and static activities (e.g., standing). The activity determined by the MLP **110** is then stored, with a date/time stamp, in the past activities database **118** (block **222**).

While the MLP **110** is controlled to make a determination as to the nature of the activity of the wearer, date/time stamped data is also being provided to the context database **116**. For example, in embodiments incorporating a GPS sensor in a sensor suite 140_{1-x}, GPS data may be obtained at a given periodicity, such as once every thirty seconds, transmitted to the processing circuit **106** and stored in the context database **116**. Additionally, data identifying the other transmitters in the piconet **142** is stored in the context database. Of course, transmitters within the piconet **142** need not be associated with a wearable sensor 102_x. For example, a cellular telephone or PDA without any sensors may still emit a signal that can be detected by the sensor 102_x.

The data within the memory **108** may be used in various applications either in real time, for example, by transmitting data over the communications link **124** to the sensor 102_x, or at another time selected by the wearer or other authorized individual by access through an I/O device **104_x**. The applications include activity monitoring, activity recording, activity goal setting, and activity reviewing.

A screen which may be used to provide activity monitoring data from the memory **108**, such as when the data is accessed by an I/O device **104_x** connected to the memory **108** by an internet connection, is depicted in FIG. **6**. The screen **230** includes a navigation portion **232** and a data portion **234**. A number of folders **236** are rendered within the data portion **234**. The folders **236** include a summary folder **238**, an activity monitoring folder **240**, an activity recording folder **242**, an activity goal setting folder **244**, and an activity reviewing folder **246**. The summary folder **238** includes a chart **248**. Data that may be rendered on the chart **248** include identification of the individual or subject associated with the sensor **102_x**, summary fitness data, and other desired data.

By selecting the activity monitoring folder **240**, the folder **240** is moved to the forefront of the screen **230**. When in the forefront, a viewer observes the folder **240** as depicted in FIG. **7**. The activity monitoring folder **240** displays data related to the current activity of the subject. In this embodiment, the activity monitoring folder **240** displays data fields **252**, **254**, and **256** which are used to display the type of activity, the duration that the activity has been engaged in, and the calories used during the activity, respectively. The data fields presented for different activities may be modified. For example, if the subject is sleeping, the data fields may indicate respiration rate, heart beat rate, and blood oxygen content.

The activity monitoring folder **240** further identifies other subjects or individuals in proximity to the monitored subject in a context window **258**. The context window **258** may identify specific individuals if known. A map **260** is also shown. Data for rendering the map **260** may be obtained, for example, from a GPS sensor in the sensor suite **140_x** or from data obtained from a relay station. For embodiments including a GPS sensor in the sensor suite **140_x**, or other sensor for obtaining detailed location data, the route **262** of the subject over the course of the monitored activity may also be displayed on the map **260**.

By selecting the activity recording folder **242** from the screen **230** of FIG. **6**, the folder **242** is moved to the forefront of the screen **230**. When in the forefront, a viewer observes the folder **242** as depicted in FIG. **8**. In this embodiment, the activity recording folder **242** displays editable data fields **264**, **266**, and **268**. The editable data fields **264**, **266**, and **268** allow a user to add or modify information related to a recorded activity. For example, unidentified workout partners may be identified to the network **100** by editing the field **268**. This data may be used to modify the context database **116** so that the network **100** recognizes the workout partner in the future. For example, an individual's identity may be associated with a particular cell phone beacon that was detected with the wearable sensor **102_x**. The activity recording folder **242** may include additional editable fields.

By selecting the activity goal setting folder **244** from the screen **230** of FIG. **6**, the folder **244** is moved to the forefront of the screen **230**. When in the forefront, a viewer observes the folder **244** as depicted in FIG. **9**. In this embodiment, the activity goal setting folder **244** displays editable data fields **270**, **272**, and **274**. The editable data fields **270**, **272**, and **274** allow a user to record goals for future activity. For example, a goal of running may be identified in the field **270** and a duration of 90 minutes may be stored in the field **272**. Additionally, a distance goal of, for example, 14 miles may be edited into field **274**. The activity goal setting folder **244** may include additional editable fields such as average speed, etc.

By selecting the activity reviewing folder **246** from the screen **230** of FIG. **6**, the folder **246** is moved to the forefront of the screen **230**. When in the forefront, a viewer observes the folder **246** as depicted in FIG. **10**. In this embodiment, the activity reviewing folder **246** displays activity data fields **276**, **278**, and **280**. The activity data fields **276**, **278**, and **280** allow a user to review activities which were conducted over a user defined time frame. Additional information may also be displayed. For example, context data fields **282** and **284** identify other individuals that were present during the activity associated with the data in the activity data fields **276** and **278**, respectively.

A variety of different screens may be used to display data obtained from the memory **108**. Additionally, the data selected for a particular screen, along with the manner in which the data is displayed, may be customized for different applications. For example, the screen **300** depicted in FIG. **11** may be used to provide an easily navigable interface for reviewing activities over a twenty-four hour window.

The screen **300** includes a navigation portion **302** and a data portion **304**. The data portion **304** includes an identification field **306** for identifying the subject and a data field **308** which displays the date associated with the data in the data portion **304**.

A daily activity chart **310** within the data portion **304** shows the amount of calories expended by the subject. To this end, bar graphs **312** indicate caloric expenditure over the twenty-four hour period depicted in the chart **310**. The data for the bar graphs **312** may be obtained, for example, from the past activities database **118**.

A focus window **314** is controlled by a user to enclose a user variable window of activity. In response, the underlying application accesses the databases **114** and displays data associated with the focus window **314** in an information field **316**, an activities field **318**, a location field **320**, and a people field **322**.

The information field **316** displays general data about the focus window **314**. Such data may include the time span selected by the user, the amount of calories expended during the selected time span, the number of steps taken by the subject during the selected time span, maximum speed of the subject during the selected time span, average speed of the subject during the selected time span, etc.

The activities field **318** displays each identifiable activity within the focus window **314**. The activity may be specifically identified or generally identified. For example, the network **100** may initially only be configured to distinguish activities based upon, for example, changes in velocity, changes in respiration, changes in heart rate, etc. Thus, the activity identification may be "activity 1," "walking," or "running".

The activities field **318** includes, however, an editable field **324**. The field **324** may be used to edit the identified activity with additional descriptive language. Thus, the general identification may be further specified as "loading boxes on a truck", "cutting grass", "raking leaves", etc. Moreover, the network **100** may be configured to "learn" so as to infer a more specific identification of future activities.

The location field **320** displays context data in the form of each identifiable location at which the activities within the focus window **314** were conducted. The location may be specifically identified or generally identified. For example, the network **100** may initially only be configured to distinguish location based upon a determined change in location. The location field **320** includes, however, an editable field **326**. The field **326** may be used to edit the identified location with additional descriptive language. Thus, the general identification of a "location 1" may be further specified as "gym", "office" or "jogging route 1".

The people field **322** displays context data in the form of each identifiable individual or subject present during the activities within the focus window **314**. The people may be specifically identified or generally identified. For example, the MLP **110** may initially only be configured to distinguish different individuals based upon a different cell phone beacons. The people field **322** includes, however, an editable field **328**. The field **328** may be used to edit the identified individual with additional descriptive language. Thus, the general identification of an "individual 1" may be further specified as "Joe", "Anastasia" or "co-worker".

Various functionalities may be incorporated into the screen **300** in addition to the functions set forth above so as to provide increased insight into the habits of a subject. By way of example, in response to selecting an activity within the activity field **318**, the context data for the selected activity may be highlighted. Thus, by highlighting the area **330** in the activities field **318**, a location **332** and individuals **334** and **336** are highlighted.

The network **100** thus provides insight as to a subject's activities such as standing, sitting, walking, fast walking and running. These activities may be inferred based upon features extracted from historical data. Additionally, by incorporation of a pre-learned classifier, such as a neural net-based classifier, the system can automatically learn new activity classifications.

The presentation of data from the databases **114** in the manner described above with reference to FIGS. **6-11** provides improved accuracy in capturing action specific metrics such as energy expenditure for walking as opposed to that for fast walking or running. By selectively displaying data stored within the databases **114**, subject matter experts (SME) can use the captured historical data to identify factors implicated by past failures for the subject. This allows the SME to design innovative and effective ways of structuring future activities so as to increase the potential for achieving goals.

Additionally, while the data may be used retrospectively, the data may also be presented to a subject in real-time. Accordingly, an athlete may easily change his workout routine from walking to running and fast walking so as to maintain a desired rate of energy expenditure. Feedback during activities may be facilitated by provision of the sensor $\mathbf{102}_x$ as a wearable device. To this end the wearable sensor $\mathbf{102}_x$ may be embodied as a small device (e.g., a smart phone with inertial sensor) that can be easily worn on the human body (e.g., on the hip or on the arm) or worn by other subject without affecting actions of daily living or recreational activities. Of course, the functionality of the network **100** can be expanded by provision of additional sensors located at multiple locations of the subject body.

The network **100** may further be used to set goals and to monitor activities against the established goals. The data may be used to provide motivational feedback to the subject.

While the invention has been illustrated and described in detail in the drawings and foregoing description, the same should be considered as illustrative and not restrictive in character. It is understood that only the preferred embodiments have been presented and that all changes, modifications and further applications that come within the spirit of the invention are desired to be protected.

The invention claimed is:

1. A physical activity monitoring system comprising:

a communications network;

a wearable sensor device configured to generate physiologic data associated with a sensed physiologic condition of a wearer, and to generate context data associated with a sensed context of the wearer, and to transmit the physiologic data and the context data over the communications network;

a memory for storing a multilayer perceptron model, the physiologic data and the context data;

a computer and a computer program executed by the computer, wherein the computer program comprises computer instructions for executing the multilayer perceptron model using acceleration data and energy expenditure data, rendering first data associated with the physiologic data and second data associated with the context data; and

a user interface operably connected to the computer for rendering the first data and the second data, wherein the first data comprises an inferred activity in which the wearer participated, the inference based upon the executed multilayer perceptron model.

2. The system of claim **1**, wherein the wearable sensor device is configured to generate the context data based upon a signal received by the wearable sensor device.

3. The system of claim **2**, wherein the received signal is a global positioning satellite (GPS) signal.

4. The system of claim **2**, wherein the received signal is a signal transmitted by a portable electronic device.

5. The system of claim **1**, wherein the second data comprises:

the identification of an individual in the company of the wearer when the physiologic condition was sensed.

6. The system of claim **1**, wherein the computer program comprises computer instructions for rendering:

activity information data;

activity recording data;

activity goal setting data; and

activity reviewing data.

7. The system of claim **1**, wherein the computer program further comprises computer instructions for executing the multilayer perceptron model to:

determine a change in a y-axis orientation of the wearer;

determine a change in a z-axis orientation of the wearer;

determine a change in a three dimensional velocity of the wearer;

determine if there is a periodic acceleration in the z-axis using an autocorrelation function; and

determine a spectral flatness measure of power spectral density coefficients.

8. The system of claim **7**, wherein the computer program further comprises computer instructions for executing the multilayer perceptron model to:

calibrate the multilayer perceptron model with a first transmitted physiologic data.

9. The system of claim **7**, wherein the computer program further comprises computer instructions for executing the multilayer perceptron model to:

analyze a relative inclination, the determined periodic acceleration, and the spectral flatness to distinguish between a sitting activity, a standing activity, and a lying-down activity.

10. The system of claim **7**, wherein the computer program further comprises computer instructions for executing the multilayer perceptron model to:

analyze the energy expenditure data, a velocity, the determined spectral flatness, and the determined periodic acceleration to distinguish between a dynamic wearer activity and a static wearer activity.

11. The system of claim **7**, wherein the computer program further comprises computer instructions for executing the multilayer perceptron model to:

perform a hyperbolic tangent sigmoid activation function for a hidden layer; and

perform a log sigmoid activation function for an output layer.

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